

Electromyography comparison of normal chair-desk system and assistant chair-desk system on fatigue

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Abstract. [Purpose] This study was designed to test the effects of the Assistant Chair-Desk System (ACDS), which can reduce the forward tilt of the neck and trunk and the level of fatigue during long lasting study in the sitting position. [Subjects] Fourteen middle school students and 14 college students of mixed gender participated in this study. [Methods] Fatigue level, the trapezius muscle, and the forward tilt angle of the head and trunk as well as distance factors were assessed before after using a normal chair-desk system (NCDS) and the ACDS for 120 minutes. [Results] There was an interaction effect in the angle and length of the neck from the sitting posture changes after 2 hours of studying using the NCDS and ACDS. There were also significant differences in the fatigue levels, hip joint angles and the lengths from the head according to the main effects of the chair-systems. [Conclusion] The studying position while using the ACDS was determined to prevent significant fatigue levels of the muscle and body, provide support to the head, by limiting the forward movement of the neck, and prevent forward tilt of the neck and trunk, by enabling the target point and gaze to be closer to the horizontal direction.

Key words: Chair-desk system, Fatigue, Posture

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INTRODUCTION

The habit of maintaining good posture during daily activities is significantly important. Good posture means a posture that can minimize the level of fatigue on the body resulting from gravity and external forces^{1, 2)}.

It has been reported that Korean middle school and college students spend 2/3 of the day in a sitting position while

studying, using a computer, watching TV, etc^{1, 3)}. The relative position of the head and trunk, when maintaining good posture in a sitting position, works as an important factor in the onset of physical fatigue⁴⁾. In the standing position, the body posture is maintained using the neck, spine and musculoskeletal system of the lower limbs; however, in the sitting position while studying, the trapezius muscle is used to support the forward tilt of the head (7–8% of the overall body weight), and maintaining the posture for a long time causes a rapid increase in fatigue. When fatigue of the trapezius muscle increases, the neck and spine experience increased instability, which causes problems such as forward head posture and affects muscle pain and the spine in negative ways^{5, 6)}. Therefore, various studies have been conducted to understand the correlation between long-term sitting postures and pain in the neck and shoulders^{7, 8)}.

Korean middle school, high school and college students

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mostly use horizontal tables and vertical-backed chairs for studying. The design conforms to Korean Industrial Standards, but its effect on the prevention of forward tilt of the head during activities such as reading and writing is minimal. Therefore, the necessity of implementing a design to prevent neck and trunk pain during studying has been recognized^{9, 10}. Furthermore, it has been reported that the neck and trunk pain of students due to studying is highly related to the sitting position while using school chairs^{7, 11}.

In extended study sessions using a desk and a chair, forward tilt of the neck and trunk occur if the gaze level is lower, which makes it the main factor in the onset of neck and spine pain¹².

Chairs should be designed to endure the pressure of the body, and to support the body weight, while desks need to be able to handle the various studying functions such as reading and writing. Through the provision of a design in which the gaze level does not change significantly, the pressure on the cervical spine and the lumbar spine could be reduced, which would be a useful way of preventing muscle fatigue^{10, 13}.

If the head is located relatively forward compared to the trunk, it changes the head, neck and physical alignment, causing pain in the head, neck and spine, while also negatively affecting the balanced growth of the body^{14, 15}. This change in physical alignment in the sitting posture is a risk factor affecting body and trunk alignment. Since Korean students maintain the forward tilt position of the head even during rest after study, due to the increased use of smart phones and longer use of them, their levels of muscle and physical fatigue rises even more, since contraction-relaxation is decreased.

It was reported that the electromyography (EMG) activity level of the trapezius muscle, which covers wide areas of the neck, back and shoulders and is the muscle most affected maintaining a fixed posture of the head, and the change of physical fatigue level have a close relation¹⁶. In addition, it has been reported that the EMG signals of the trapezius muscle measured using surface EMG can be used as an indicator of muscle fatigue, especially the decrease of Mean Power Frequency (MPF)¹⁷. Previous research has indicated there is a very close relation between the trunk movement due to sitting on chairs, and the activity level of the erector muscles of the spine^{17, 18}. Upon reviewing the postures adopted while sitting in various chairs, which can cause changes in physical posture during work, differences in posture were found based on the methods used to adjust the level of gaze and monitor height¹³. Desks and chairs should therefore be designed to reduce the pressure on the waist by dispersing the weight over a wider area, and to offer the height that is best for gaze level during study, since students use desks and chairs for many hours¹⁹.

However, for typical Korean students, if the height of the desk were unilaterally adjusted for the gaze level, it might have negative effects on other activities since the desks are also needed for other activities. Therefore, this study compared assistant desks (which can reduce the fatigue level of the trapezius muscle through reducing the change in the gaze level during study and reducing the pressure on the neck while performing various tasks) and assistant chairs (that can prevent lumbar spinal tilt) with normal desks and

chairs to verify the effects of the assistant chair-desk system (ACDS), which can minimize the forward tilt of the neck and trunk.

SUBJECTS AND METHODS

The study subjects were 14 middle school students (14 years of age, 159.4 ± 8.9 cm in height, weighing 50.3 ± 9.2 kg, with skeletal muscle mass of 21.2 ± 5.1 kg and 530 ± 156 minutes study time/day) and 14 college students (24.2 \pm 2.4 years of age, 168.2 ± 10.8 cm in height, weighing 63.8 ± 16.8 kg, with skeletal muscle mass of 27.5 ± 7.5 kg and 389 ± 146 minutes study time/day) of mixed gender.

The ACDS was developed in 2013. It consists of an assistant desk which can be adjusted to facilitate the best gaze level of students and also has an adjustable backrest on the chair so that the students can study comfort (Back Solution, HAAN Co., Korea). The assessment of fatigue level was done using a fatigue testing device (FT-501, Dongsan Trading, Korea), which measures the fatigue level using the flicker fusion frequency of the students during rest and after studying using a designated chair¹⁶. Measurements were carried out after letting the students take a rest for 10 minutes while blindfolded. They were taken before and after 120 minutes of study by the students to measure their fatigue levels.

EMG signal analysis of the trapezius muscles was carried out with bipolar (20 mm center-to-center, 10 mm of diameter) Ag-AgCl surface electrodes (Noraxon, USA). The electrodes were placed on the skin close to each other at a point midway between the spinous process of the 7th cervical vertebral and the outer edge of the acromion²⁰. The ground electrode was attached over the 7th cervical spine. Each electrode spot was marked with an oil pen and secured with surgical tape, after the skin had been shaved and cleaned with alcohol, to ensure that the electrode stayed on the same spot during the test measurement.

The EMG signal was recorded continuously during the study period. The signals were amplified and bandpass filtered between 10 to 2,000 Hz (Noraxon Telemysystem 900, USA; common mode rejection ratio: 100 dB at 60 Hz; differential input impedance: 10 M Ω ; gain: 2,000; base-line noise < 1 μ V), and then converted from analogue to digital at a sampling frequency of 1,000 Hz.

Measurements of the head and trunk forward tilt and distance were obtained by recording the study posture with a video camera (HDV 1080i, Sony Co., Japan) while not interrupting studying as much as possible. The camera was placed 1 m in front of the desk and the camera height was adjusted to maintain horizontal position. Image data were obtained 20 minutes and 100 minutes after the beginning of the study. Statistical analysis was done using SPSS 18.0 to verify before and after differences in the fatigue level, mean power frequency slope (MPFS) of the trapezius muscles, and forward tilt angle of the head and trunk of the normal chair-desk system (NCDS) the assistant chair-desk system (ACDS) using independent two-way repeated ANOVA (2 type X 2 repeated). Significance was accepted for values of $p < 0.05$.

Table 1. The mean power frequency slope of trapezius muscle between NCDS and ACDS before and after 2 hours of study

Condition	Initial time Mean (\pm SD)		After 2 hours of study Mean (\pm SD)		Main effect		Interaction effect
	NCDS	ACDS	NCDS	ACDS	Time interval	Chair system	
Left trapezius muscle mean power frequency slope	-0.32 (1.24)	0.02 (0.36)	-0.07 (0.40)	0.03 (0.31)	0.093	0.302	0.383
Right trapezius muscle mean power frequency slope	0.11 (0.51)	-0.03 (0.35)	0.22 (0.53)	-0.08 (0.61)	0.028***	0.780	0.415
fatigue	4.11* (3.41)	4.09 (4.19)	6.17* ^b difference (3.85)	4.82 ^b (3.76)	0.007***	0.033***	0.079

*_b*** $p < 0.05$; difference between time intervals: * = initial value vs after 2 hours of study in NCDS; difference between groups: ^b = NCDS vs ACDS after 2 hours of study; *** = main effect and interaction effect

Table 2. The neck and hip angles in the sitting position of the NCDS and ACDS before and after 2 hours of study

Condition	Initial time Mean (\pm SD)		After 2 hours of study Mean (\pm SD)		Main effect		Interaction effect
	NCDS	ACDS	NCDS	ACDS	Time interval	Chair system	
Neck angle	26.8* ^a (13.5)	43.1** ^a (1.0)	18.4* ^b (8.5)	47.1** ^b (5.7)	0.001***	0.092	0.001***
Hip angle	92.7 ^a (12.9)	105.6** ^a (9.2)	90.2 ^b (13.0)	101.2** ^b (9.3)	0.001***	0.006***	0.510

_{a,b} $p < 0.05$; difference between time intervals: * = initial value vs 2 hours after in NCDS, ** = initial value vs 2 hours after in ACDS; difference between groups: ^a = NCDS vs ACDS before studying, ^b = NCDS vs ACDS after 2 hours of study; *** = main effect and interaction effect

RESULTS

In this study, no interaction effect ($p > 0.05$) was found between the MPFS of the left or right trapezius muscles and the fatigue level of the 28 participants after 2 hours of studying using either the NCDS or ACDS. From the main effect verification based on the time interval, the right trapezius muscle MPFS ($F=5.407$, $p=0.028$) and fatigue level score ($F=8.473$, $p=0.007$) showed significant differences, and there was also a significant difference in the fatigue levels according to the main effect of the two chair systems ($F=5.056$, $p=0.033$).

For NCDS, there was a significant difference in the fatigue level after 2 hours of studying ($t=-3.578$, $p=0.001$). In addition, a significant difference in the fatigue levels of the NCDS and ACDS was also found after 2 hours of studying (Table 1). Among the changes in sitting posture found after 2 hours of studying utilizing the NCDS or ACDS, an interaction effect was found only for the neck angle ($p < 0.05$). According to verification of the main effects based on time intervals, a significant difference was present in the neck angle ($F=390.27$, $p=0.001$) and hip joint angle ($F=43.10$, $p=0.001$). Based on the chair systems, there was a main effect only for the hip joint angle ($F=9.01$, $p=0.006$).

After 2 hours of studying, there were significant differences in the neck angles of both the NCDS ($t=4.848$, $p=0.001$) and ACDS ($t=-2.707$, $p=0.012$), but only the ACDS ($t=2.438$, $p=0.022$) showed a significant difference in the hip joint angle. Between the NCDS and ACDS, sig-

nificant differences were found in the neck angle ($t=-8.385$, $p=0.001$) and hip joint angle ($t=-6.325$, $p=0.001$) measured before the study, and also in those measured after 2 hours of studying (neck angle, $t=-29.661$, $p=0.001$; hip joint angle, $t=-4.205$, $p=0.001$; Table 2).

An interaction effect ($p < 0.05$) was found between the length of the head to C7 (7th cervical vertebra) and the head to T12 (12th thoracic vertebra) in the sitting position, measured after 2 hours of studying with both the NCDS and ACDS. According to the main effects based on time intervals, significant differences were also present in the length of the head to C7 ($F=506.34$, $p=0.001$) and the length of the head to T12 ($F=353.08$, $p=0.001$). In addition, significant differences in the length of the head to C7 ($F=7.44$, $p=0.011$) and the length of the head to T12 ($F=7.02$, $p=0.013$) present according to the main effects of the two on chair systems.

After 2 hours of studying, there was a significant difference in the length of the head to C7 ($t=-4.804$, $p=0.001$) and the length of the head to T12 ($t=-3.854$, $p=0.001$) in NCDS, but not in ACDS. There was also a statistically significant difference of the length of the head to C7 ($t=12.182$, $p=0.001$) and the length of the head to T12 ($t=8.876$, $p=0.001$) between NCDS and ACDS, as measured before the experiment. Finally, a significant difference was found in the length of the head to C7 ($t=21.617$, $p=0.001$) and the length of the head to T12 ($t=33.552$, $p=0.001$) between NCDS and ACDS after 2 hours of studying (Table 3).

Table 3. Length from the head to the 7th cervical vertebra and the head to the 12th thoracic vertebra in the sitting position of the NCDS and ACDS before and after 2 hours of study

Condition	Initial time Mean (\pm SD)		After 2 hours of study Mean (\pm SD)		Main effect		Interaction effect
	NCDS	ACDS	NCDS	ACDS	Time	Chair system	
Length from head to C7	25.5 ^{*,a} (3.23)	21.3 ^a (2.73)	27.4 ^{*,b} (2.82)	21.0 ^b (1.88)	0.001***	0.011***	0.001***
Length from head to T12	36.1 ^{*,a} (6.14)	24.3 ^a (4.58)	39.0 ^{*,b} (4.30)	26.9 ^b (3.36)	0.001***	0.013***	0.003***

^{*,a,b,***}p < 0.05; difference between time intervals: * = initial value vs after 2 hours of study in NCDS; difference between groups: ^a = NCDS vs ACDS before studying, ^b = NCDS vs ACDS after 2 hours of study; *** = main effect and interaction effect

DISCUSSION

The sensation of fatigue consists of ocular symptoms, visual experience and physical fatigue factors, and the level of fatigue has been reported to have a close correlation with body coordination movements and the distance and angle of the gaze²¹). In addition, a significant change in the level of muscle activity was found in an analysis of the left and right trapezius muscles under different conditions of types of chair and work being done¹³). The characteristics of the trapezius muscle were observed while performing static contractions²²), and the results indicate that the trapezius muscle plays a major role in fixing head movement during study or work performed using desks and chairs. The result can also be interpreted as showing that the trapezius muscle is used to maintain fixed posture because of movement of the head location, due to desk and chair design, which determine the direction of the gaze while in a sitting position. The trapezius muscle has increased activity when moving to lower the gaze than when a monitor and the corresponding gaze are in a horizontal line, despite the use of the arms in various tasks on the table²³).

The present study found a difference only in the MPF slope of the trapezius muscle after studying. This can be interpreted as a result of mostly using the right hand while studying, since the participants were all right-handed. Long-term sitting while using a desk and chair increases the risk of pain in the cervical spine and the lumbar spine, and thus studies on the functions of various desks and chairs are ongoing²⁴). The weight of the head segment is relatively heavy (about 8% of the body), but the muscles supporting that segment are not bigger than the other muscles. This situation can easily cause fatigue during maintenance of posture, and furthermore, can cause diseases such as spinal disk disease. Therefore, the stability of the head segment is important, especially in a sitting posture which involves maintenance of posture for a long period, and the lower the level of the forward tilt of the head, the less the level of fatigue due to decreased fatigue of the muscles supporting the head²⁵).

In general, head movement is known to induce more instability than hip movement in terms of physical balance²⁶). For students who spend many hours studying using a desk and a chair, the use of the ACDS, which can decrease the

forward tilt of the head and trunk, would help to increase their studying capacity by reducing study-related fatigue. The authors also believe that it would also be effective at reducing the risk to the cervical spine of incurring spine distortions and diseases, while also decreasing head and physical pain. In a comparison of the head and neck postures and physical measurement characteristics of 985 Australian youths, a group with head and neck pain had a forward head tilt that was 4.8° less than that of a group without pain, thus indicating a correlation between forward tilt of the head and pain of the head and neck¹¹). It was also reported that a chair offering backward tilt was more comfortable in a study of backrest angles for work comfort¹⁰), and a chair angle supporting a horizontal gaze showed¹³) was more vertical the angle of the lumbar spine, which determines the forward tilt of the trunk. This can be interpreted as facilitating decreased forward tilt of the trunk.

Having a horizontal gaze is more effective at maintaining relative comfort when studying for a long time using a desk and a chair. To obtain that goal, the forward tilt of the head and trunk should be minimized¹³). Although the forward tilt of the head of the NCDS subjects increased in NCDS after 120 minutes of studying in the present study, the ACDS subjects showed a relative decrease in the horizontal length change of the head to C7 and the head to T12 after 2 hour of study, and decreased forward tilt of the head and trunk was observed.

Korean students generally study for a long time while sitting on a chair with a horizontal desk. This posture eventually increases the forward tilt of the head, thus making the trapezius muscles continuously perform eccentric contractions to prevent forward tilt, causing increase in muscle fatigue and subsequent increase in the physical fatigue level. Therefore, the ACDS used in this study appears to allow the maintenance of a more stable study posture by enabling a spinal curve through the use of an assistant chair to disperse the vertical pressure on the lumbar spine and by minimizing the head tilt to support a relatively horizontal gaze. This study revealed that when studying for a long time, the ACDS can reduce the level of fatigue compared to the conventional NCDS, since it minimizes dislocation of the head from the central line of the body.

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